

**HIGH EXPLOSIVE WASTES  
RECENT EXPERIENCES IN AUSTRALIA AND  
AVOIDANCE TECHNIQUES IN A NEW  
FACILITY**

**by**

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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>AUG 1990</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-1990 to 00-00-1990</b>	
4. TITLE AND SUBTITLE <b>High Explosive Wastes - Recant Experiences in Australia and Avoidance Techniques in a New Facility</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Australian Defence Industries Ltd, ,Canberra, Australia,</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADA235005, Volume 1. Minutes of the Explosives Safety Seminar (24th) Held in St. Louis, MO on 28-30 August 1990.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>33</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## **ABSTRACT**

Australian Defence Industries Ltd (ADI) is managing the closure of a high explosive and propellant manufacturing facility in suburban Melbourne. The site is to be made available for housing, recreation and commercial purposes. A number of issues have arisen in relation to soil decontamination in an environment of changing Government and public perceptions.

In reconstructing the explosives and propellant processes at a new site in rural Mulwala in New South Wales, which is located in a sensitive water supply area, new approaches have been taken to address waste problems.

## Introduction

### ADI Ltd

The Australian ammunition and explosives industry has undergone significant change and restructuring in the past 18 months.

On 3 May 1989 the Government created a new Government owned Company to run the defence factories and dockyard previously part of the Department of Defence. This company, Australian Defence Industries Ltd, is now Australia's largest defence equipment manufacturing and services company, employing around 6000 people.

Its products and services include:

- . Naval Engineering
- . Electronics
- . Weapons
- . Ammunition
- . Training Systems
- . Clothing

ADI facilities are geographically widespread, including a regional office in Malaysia.

Prior to the creation of ADI, restructuring of Australia's munitions industry had commenced with the closure of the high explosives manufacturing capability at Albion Explosives Factory in Melbourne Victoria and the announced closure of one of the oldest explosives establishments, Explosives Factory Maribyrnong - to occur in a year or two.

The high explosives capability is being transferred to an existing propellant manufacturing facility at Mulwala NSW.

ADI's retains the management of the closure of both establishments.

For many of you the closure of such establishments, and the legacy as a result, is no novelty. For us, however, this has been a significant event and has raised some particular problems which may be of interest and wider relevance.

In this paper, I will describe issues which have arisen in relation to decontamination, the attitudes of Government and public perceptions towards this process for the Albion Explosives Factory closure, and then outline our approach to avoiding future environmental problems in the relocation of this capability at Mulwala, NSW, a site of significant environmental sensitivity (located on the river Murray, the largest river in Australia and a crucial source of water for many purposes).

## The Closure of Albion Explosives Factory

Profile of Albion is as follows:

- Site:
- 20 kilometres West of Melbourne
  - now surrounded by residential properties
  - about 500 hectares (1250 acres): 2km x 2.3km
  - adjacent creeks (can affect 4 rivers which pass through heavily populated areas)
  - 349 buildings at time of closing
  - safeguarding problems (purple line incursions)

History of the establishment:

- |      |   |
|------|---|
| 1939 | Constructed by ICIANZ                           |
| 1940 | Manufacture TNT, NG, Cordite, chemicals         |
| 1948 | Care and Maintenance                            |
| 1954 | Reopened (RDX plant added)                      |
| 1957 | Solvent less double base propellant plant added |
| 1971 | Continuous TNT plant installed                  |
| 1975 | A major effluent plant was constructed          |
| 1986 | Closed  |

### Capabilities:

The following products were being made at the time of closing:

High Explosives - TNT, RDX, Comp B, RDX/WAX, Plastic Explosive  
2, 4 Dinitrotoluene  
Nitroglycerine  
Gun, rocket propellants  
Nitric, Sulphuric acid concentration and processing

### Environmental

Aspects of environmental significance at Albion were:

- . Major effluent plant not constructed until 1975 (lime slurry neutralisation plant)
- . Concrete settling tanks, labyrinths (cracking problems)
- . Earthenware drains (clay soil problems)
- . Acidic effluents neutralised in old pits using limestone with discharge to creek systems
- . Breaches of effluent discharge levels to sewer when sewer pipes failed
  - red water to sewer during the war; and to adjacent paddocks
  - red water spillages

- . Asbestos burial
- . Waste disposal (open ground burning), plant decontamination.

Once the traumas of the closure were overcome the key staff retained proceeded to carry out an orderly closedown. Using the knowledge of current and past members of the workforce areas of possible contamination were generally identified. A formal study of the Site was initiated and soil sampling began. The limits of allowable contamination in the soil after reclamation were sought from the Environmental Protection Agency (EPA).

The Government appointed a Steering Committee made up of community, municipal, State and Federal officers. A concept plan for Albion was developed and included proposals for:

- residential housing
- recreation land
- light industrial
- a possible lake and golf course

Unfortunately the political process does not work so smoothly and a sequence of events occurred which has created particular difficulties, as yet unresolved:

- a. Government Housing summit: needing an electoral boost the Federal Government called a housing summit - land was needed - Albion was the 'jewel in the crown' of the Victorian parcel of Federal land to be offered up.
- b. Community, Municipal and State Government hopes were further heightened.
- c. An environmental issue concerning residential land heavily polluted with lead (old battery factory site) hit the airwaves. This site was very close to Albion. Other similar contaminated sites were identified (some in prime city areas)
- d. Community, union, government pressures developed - some 50 contaminated sites were officially identified in Victoria by the EPA (all non Defence related)
- e. This resulted in a focus on Albion and clamour for "total freedom from contamination". The attitude is typified in a quotation from a Union Spokesman (reference 7).

"... the union will only accept a level of contamination that will not present any increased risk to the future occupants of the site. They want the whole site cleared and not just the selected areas of contamination".

- f. The EPA retreated to its bunker and we still await a statement of what the levels of contamination should be - zero?

### Contamination levels

The results of the contamination study have indicated that the residual contamination was (as expected) localised and in general in relatively low levels. Based on 34.5 hectares surveyed of the 500 hectares and from 1000 excavations to at least 1 metre depth, only 1% (5 hectares) of the total area could be considered contaminated.

The levels and concentration varies from site to site and the bulk of contamination lies primarily in the south west **near the high explosives areas**. The contamination is however very scattered across the site but each site can be identified. The contaminants are primarily organics associated with high explosives manufacture. Of the total volume of soil covered by the survey about one sixth was found to be contaminated. The distribution of the contaminants is as follows:

<u>Contaminant</u>	<u>% of the volume of the soil which contains these contaminants</u>
Nitroaromatics (TNT, 2,4 DNT, 2,6 DNT)	40%
Heavy metals	20%
RDX	15%
Acids, Sulphates	20%
Mixtures	5%

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Over 90% of the material contains from two to three times the recommended acceptance criteria (in the low parts per million range). The remainder contains up to several hundred times the recommended acceptance criteria (hundred to thousands ppm). These recommended criteria are levels we have evolved ourselves using risk assessment and available medical evidence. We have had a lot of difficulty in determining what limits are applied internationally.

Fortunately the soil is heavy basaltic clay with fractured basalt seams and the contaminants have been securely held. Bedrock is at about 3 metres and contamination is distributed down to this level. Groundwater contamination is also probable but the degree has not yet been quantified.

Hence we have a situation where there are localised levels of low contamination with occasional "hot spots" of relatively heavy contaminants.

As a consequence of all these factors, we now face a dilemma:

- . Relatively low levels of contamination
- . Difficulties in obtaining technologies to reduce low levels to even lower levels (current technology appears to address removal of gross levels)
- . A tradeoff between cost of decontamination and the revenue expected for the land
- . Community anxieties and fading aspirations.

We believe we will need a multiple treatment type approach. We are still exploring options such as thermal techniques, composting and biodegradation. Our options will be driven by the limits set by the EPA. We are confident that solutions can be found which are able to be operated successfully. Because of the high political interest, cost is becoming a lesser consideration to the achievement of a total clean up. The question is however, what does "clean" mean. We are working very closely with the EPA to obtain a resolution of these matters.



### **New High Explosives, propellant capability Mulwala NSW**

In the second part of my paper I wish to outline the approaches we have taken in reconstructing this capability to avoid a future legacy of contamination for our successors. In line with the theme of this paper I will be focussing primarily on liquid effluent issues. I should point out that the processes described below are not to be run for extended periods, ie production will be staged using short runs.

#### **The Site**

The site of the existing Mulwala Explosives Factory was chosen for the new high explosive capability. This facility is located on the border in New South Wales and is about 1 kilometre north of the Murray River. The land is relatively flat, sandy agricultural land.

The Facility is located in a sensitive water environment. The Murray river, the largest in Australia flows halfway across the continent to South Australia and provides a vital agricultural lifeline. The salinity of the water is an ongoing and very significant national problem. At Mulwala the river has been dammed to form Lake Mulwala and two main irrigation supply channels are drawn from this to service NSW and Victoria. Continuous water quality monitoring is carried out downstream of the lake and is of a high quality. Also adjacent to the river are a number of billabongs or ponds.

The soil is an alluvial sequence of sands, gravels and clays down to 100M. Underground leakage from the Mulwala canal occurs and liquid contaminants could pass through the clayed upper zone to the water table.

#### **Mulwala Facility's Products and Capabilities (present and planned).**

##### **Current products:**

- . extruded double base and single base propellants for small arms ammunition and medium calibre ammunition
- . rocket propellants and casting powders
- . nitrocellulose
- . nitric acid
- . nitroglycerine
- . ether

The new capabilities now under construction (and scheduled to be completed in 2 years) are:

- . TNT - we will be re-installing basically the same process used at Albion employing continuous multi stage counter current flow for the trinitration of toluene.

- . RDX - again we are reinstalling the existing continuous Woolwich process to produce RDX by the nitrolysis of hexamine using 98% nitric acid and purification by recrystallisation from cyclohexanone.
- . Propellants - new gun propellant facilities employing screw mixer extruder technology.
- . Ancillaries - laboratory, bulk toluene storage, burning ground, acid concentration.
- . Control system - one of the most significant changes has been the incorporation of a Distributed Control system to remotely monitor and control the RDX and TNT processes. This will ensure operator health and safety, improved product quality and increased safety. Needless to say, a well run process is basic to controlling environmental problems.

### **Addressing Environmental Issues**

#### **Basic principle**

The basic principle is one of total containment of primary liquid effluents.

The existing factory does currently discharge process waters from the acid concentration plant to the river and we are developing ways to deal with this. I will enlarge on this later.

In broad terms containment will be achieved by:

- a. Dedicated on site effluent treatment. The TNT and RDX plants will have an effluent treatment plant integrated with the process. I will discuss this below.
- b. Above ground piping has been used extensively to allow ease of maintenance and inspection.
- c. In the process buildings we have used open, accessible drains to catch any spillages or washings. Considerable effort has been expended in designing the floors so that wash waters are contained. We have used impervious concrete structures with particular attention to joints and taken care to reduce the likelihood of cracks. All open drains have continuous stainless steel liners.
- d. Carbon columns are an integral part of the process effluent systems.
- e. Some specialised processes have been incorporated to deal with or reduce effluent levels in the TNT process. We will employ a proprietary process for acid waste treatment (organic and nitrobody removal) and we have an incinerator process to deal with red water.

- f. No formal system of stormwater collection is proposed for the new area. The potential for discharge from the area of contaminated stormwater will be minimised by:
- . use of drains in the paving around process buildings which will drain to the effluent treatment system.
  - . bunding of tankage areas and tanker docks.
  - . bunding of manufacturing, handling and packaging areas. Such areas will be roofed.
  - . special procedures to deal with spills in unbunded areas. (Given the long distances to the boundary and the permeable nature of the soils, we consider the possibility of spilled liquids reaching surface waters to be negligible.)
  - . wastewater recirculation is a feature of the RDX plant and has been maximised in re-installing the process.
  - . final effluents from the two processes will be collected in evaporation ponds which have been designed with sufficient storage capacity. Evaporation is well in excess of rainwater on an annual basis. I will describe these ponds in greater detail later.

### Process Effluents

These proposals can be illustrated by examining the main processes in turn:

a. TNT Process Effluents

Main effluents from this process are:

- red water, from the sulphiting purification process
- pink water, from general wash water and other sources
- fume scrubber waste.
- nitrous compounds and organics in the waste acid stream

The red water will be disposed of by complete incineration in a gas fired rotary hearth furnace which was developed at Albion. Ash arisings (95% sodium sulphate, the rest carbon) are accepted for land fill.

The pink water, ie the washings collected in drains and fume scrubber wastes are collected in a brick lined pit, neutralised (sodium sulphite), passed through an activated carbon column and the residual stream sent to the large TNT effluent evaporation pond.

Waste Acid Stream - the waste acid stream from the nitration process carries over nitro-organic contaminants and if we had retained our existing process to reconcentrate the weak sulphuric acid, we would have to deal with a contaminated effluent. Again, we considered incineration of the effluents, but a neater solution has been effected by purchase of a proprietary chemical extraction process from Italy for waste acid purification.

b. RDX Process Effluents

In relocating the plant we have attempted to maximise recirculation of the process water to minimise liquid effluents. Previously there was no recirculation.

Process waters will be neutralised and passed through carbon absorption columns and then returned to a storage water tank. Water from this tank will then be deployed back to the process, for cooling and wash down. Any overflow from this tank will flow to the evaporation pond and any drainage will again be captured in open building drains and also eventually pass to the evaporation pond. Cyclohexanone residues will be burnt.

c. Acid Concentration Plant Effluents  
Propellant Complex Effluents

I mentioned our goal of total containment of liquid wastes. We still have one remaining problem to address as a result of the processes of the existing facility. This relates to the effluents from the acid concentration plants and the nitroglycerine plant already in operation. These effluents could also be marginally increased as a result of our new capabilities. We plan, for example, to truck effluents from the propellant process (mostly water slightly contaminated with nitroglycerine to the existing NG effluent treatment plant.) This treatment, ie neutralisation using sodium hydroxide, results in an effluent with a range of salts viz nitrates, nitrites, acetates and formate. This effluent currently goes to the river. To eliminate this we are looking at a novel solution. By the time the new capability is in place we aim to have resolved this problem.

Irrigated Forest Plantation

The option we are exploring is the use of tree plantings to deal with this effluent. One of the first projects to investigate waste water renovation by irrigating forest land was at Pennsylvania State University in 1963. A significant body of work has been done in the last decade in Australia mainly in the areas adjacent the River Murray.

The "green revolution" is of course giving a boost and encouragement to the exploration of such methods.

We are still at the feasibility study stage and we have not yet subjected this technique to rigorous analysis. A preliminary strategy plan (reference 4) has indicated there is potential for the system.

The likely problem areas are with:

- . salinity
- . reduced soil permeability
- . toxicity to crops
- . pollution of groundwater and adjacent surface waters due to the build up of chemicals.

Salinity is considered to be the most critical effluent quality parameter. The salinity of the effluent is high but it is believed by using selected planting material and careful irrigation that this is manageable. Sulphate and nitric ions, in contrast, are essential to tree growth and taken up by most plants.

The major species of tree recommended is appropriately, the flooded gum (*Eucalyptus grandis*). This is suitable for the climate, of proven vigour and is suitable for pulping. It recovers well from fire damage and can not only accommodate floods but can also withstand long periods of drought.

On the next slide I have shown some indicative cost estimates and this indicates the major elements of such a system. The analysis of input effluents and monitoring of the forest soils and waters is of course a crucial factor.

### Evaporation Ponds

Finally I wish to mention the role of the evaporation ponds I have alluded to earlier in this paper which have some interesting features.

We were aware of the now widespread use of geotextile membranes for ground water protection, landfill encapsulation and evaporation pond liners. One such local example is the containment of Magnesium chloride brine solutions in Henderson Nevada (reference 6). We considered such a system for our original design. We are not sure if such a system has been used for effluents from explosives processes. Two HDPE (high density polyethylene) sheets would be laid on the bottom separated by a permeable geotextile membrane. Any leakage into the membrane would be monitored. Above this a 100mm (4 inch) reinforced concrete layer was proposed and on top of this a further layer of acid resistant polyester.

This design appeared to have some drawbacks. Cost was one problem. Secondly, it is impossible to ensure that a concrete base such as this would not crack and so expansion joints would be required. If a crack did occur the leak would not be immediately detected as the leaked material could channel some distance before detection.

Our attention was drawn to fly ash containment ponds at major power stations at Yallourn in Victoria. This design was much simpler and consisted of a 2.5mm HDPE lining covered with 500mm of a protective sand layer.

We have modified our design and it now consists of a layer of 2.5mm HDPE on the bottom, 500mm of sand and a further layer of 2.5mm HDPE above this, which will be the surface of the pond. Along the sides of the dam we have installed a geotextile liner to compensate for any problems in gaining an effective interface at the side wall. Near the access points a protective layer of polyester is provided. Our leak detection system consists of a agricultural type pipe in the sand layer feeding to a monitoring pit with alarms. We also have installed a network of bores to assist in detecting leaks.

Should the upper liner fail we can take quick action to pump out the compartment (each pond is subdivided), visually locate the tear and effect simple repairs by welding in a new section.

Consequently, not only was the construction cost cheaper, we believe maintenance and repair also will be more economical. The care taken in installing the liner and the associated warranties give us confidence of a twenty year life.

The ponds have been filled with water for some time and up to now have withstood the effects of many visitors, with the exception of two kangaroos!

### Summary and Conclusion

In closing an explosive factory, what initially seemed a straightforward task, has resulted in a series of interesting technical, political and environmental interactions.

A heightening of local environmental awareness of the issues of land contamination, the unique nature of explosives contamination and a general dearth of reference data has produced a situation where very severe limits of residual contamination are likely to be set. Given that there appears to be a general lack of technologies in achieving marginal change at these lower levels, there are new challenges in selecting a decontamination technique.

In re-establishing similar facilities, a totally different approach has been taken to avoid such future problems. In a sensitive area we have adopted for a policy of total liquid effluent containment and turned to some novel technologies to achieve that end.

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**Acknowledgments:**

The help and contributions of Mr N. Tozer, Mr R. Smart and Mr B. Kathiravelu are acknowledged.

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**HISTORY OF ALBION  
EXPLOSIVES FACTORY**

<b>1939</b>	<b>CONSTRUCTED BY ICIANZ</b>
<b>1940</b>	<b>MANUFACTURED TNT, NG, CORDITE, CHEMICALS</b>
<b>1948</b>	<b>CARE AND MAINTENANCE</b>
<b>1954</b>	<b>REOPENED (RDX PLANT ADDED)</b>
<b>1971</b>	<b>CONTINUOUS TNT PLANT OPENED</b>
<b>1975</b>	<b>MAJOR EFFLUENT PLANT WAS CONTRUCTED</b>
<b>1986</b>	<b>CLOSED</b>



## THE CLOSURE OF ALBION EXPLOSIVES FACTORY

**PROFILE OF ALBION IS AS FOLLOWS:**

**SITE**

- 20 KILOMETRES WEST OF MELBOURNE
- NOW SURROUNDED BY RESIDENTIAL PROPERTIES
- ABOUT 500 HECTARES (1250 ACRES): 2KM X 2.3KM
- ADJACENT CREEKS (CAN AFFECT 4 RIVERS THROUGH LARGE POPULATION AREAS)
- 349 BUILDINGS
- SAFEGUARDING PROBLEMS (PURPLE LINE INCURSIONS)



## CAPABILITIES AT ALBION EXPLOSIVES FACTORY

THE FOLLOWING PRODUCTS WERE BEING  
MADE AT THE TIME OF CLOSING

- HIGH EXPLOSIVES - TNT, RDX, COMP B, RDX/WAX, PLASTIC EXPLOSIVE
- 2,4 DINITROTOLUENE
- NITROGLYCERINE
- GUN, ROCKET PROPELLANTS
- NITRIC, SULPHURIC ACID CONCENTRATION AND PROCESSING

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## **ENVIRONMENTAL ISSUES AT ALBION EXPLOSIVES FACTORY**

### **ASPECTS OF ENVIRONMENTAL SIGNIFICANCE**

- . MAJOR EFFLUENT PLANT NOT CONSTRUCTED UNTIL 1975**
- . CONCRETE SETTLING TANKS, LABYRINTHS (CRACKING PROBLEMS)**
- . EARTHENWARE DRAINS (CLAY SOIL PROBLEMS)**
- . ACIDIC EFFLUENT NEUTRALISED IN LIMESTONE PITS**
- . BREACHES OF EFFLUENT DISCHARGE LEVELS TO SEWER WHEN SEWER PIPES FAILED**
- . - RED WATER TO SEWER DURING THE WAR; AND TO ADJACENT PADDOCKS**
- . - RED WATER SPILLAGES**
- . ASBESTOS BURIAL**
- . WASTE DISPOSAL (OPEN GROUND), PLANT DECONTAMINATION**

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## **POLITICAL PROCESS - IMPACT ON ALBION CLEAN UP**

- GOVERNMENT HOUSING SUMMIT
- COMMUNITY
- OTHER SITES
- PRESSURES
- ATTITUDE
- EPA

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## Scramble for Albion

Private groups seek explosives site

### Contamination scare

Contamination on  
second site feared

Huge clean-up for poison site

Fire could have lit  
Albion "time bomb"

## Albion doubt

Contamination is higher than expected



## CURRENT SITUATION

- RELATIVELY LOW LEVELS OF CONTAMINATION
- DIFFICULTIES IN OBTAINING TECHNOLOGIES TO REDUCE LOW LEVELS TO EVEN LOWER LEVELS (CURRENT TECHNOLOGY APPEARS TO ADDRESS REMOVAL OF GROSS LEVELS)
- A TRADEOFF BETWEEN COST OF DECONTAMINATION AND THE REVENUE EXPECTED FOR THE LAND
- COMMUNITY ANXIETIES AND FADING ASPIRATIONS



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## CONTAMINATION LEVELS AT ALBION EXPLOSIVES FACTORY

- BASED ON 34.5 HECTARES SURVEYED OF THE 500 HECTARES AND FROM 1000 EXCAVATIONS TO 1M DEPTH (3000 SAMPLES), 1% OF THE TOTAL AREA (5 HECTARES) COULD BE CONSIDERED CONTAMINATED
- THE LEVEL VARIES FROM SITE TO SITE AND IS CONCENTRATED PRIMARILY IN THE SOUTH WEST NEAR THE HIGH EXPLOSIVE AREAS
- OF THE TOTAL VOLUME SURVEYED, ABOUT ONE SIXTH IS ESTIMATED TO BE CONTAMINATED

THE DISTRIBUTION IS:

CONTAMINANT	% OF THE VOLUME OF THE SOIL WHICH CONTAINS THESE CONTAMINANTS
(TNT, 2,4 DNT, 2,6 DNT)	40% BY VOLUME
HEAVY METALS	20%
RDX	15%
ACIDS, SULPHATES	20%
MIXTURES	5%

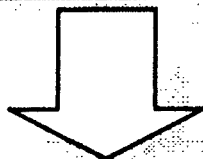




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## CONTAMINATION LEVELS

GREATER THAN  
90%  
OF MATERIAL



CONTAINS ONE TO  
THREE TIMES  
RECOMMENDED  
ACCEPTANCE CRITERIA  
(LOW PPM)

LESS THAN  
10%



SEVERAL HUNDRED  
TIMES CRITERIA  
I.E. HUNDREDS TO  
THOUSANDS PPM



## MULWALA FACILITY's PRODUCTS AND CAPABILITIES

### PRESENT

#### CURRENT PRODUCTS:

- EXTRUDED DOUBLE BASE AND SINGLE BASE PROPELLANTS FOR SMALL ARMS AMMUNITION AND LARGE CALIBRE AMMUNITION
- ROCKET PROPELLANTS AND CASTING POWDERS
- NITROCELLULOSE
- NITRIC ACID
- NITROGLYCERINE
- ETHER

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## **NEW CAPABILITIES MULWALA**

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- **TNT**
- **RDX**
- **PROPELLANTS**
- **ANCILLARIES**
- **CONTROL SYSTEM**

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## **ENVIRONMENTAL TECHNIQUES TO BE USED AT MULWALA**

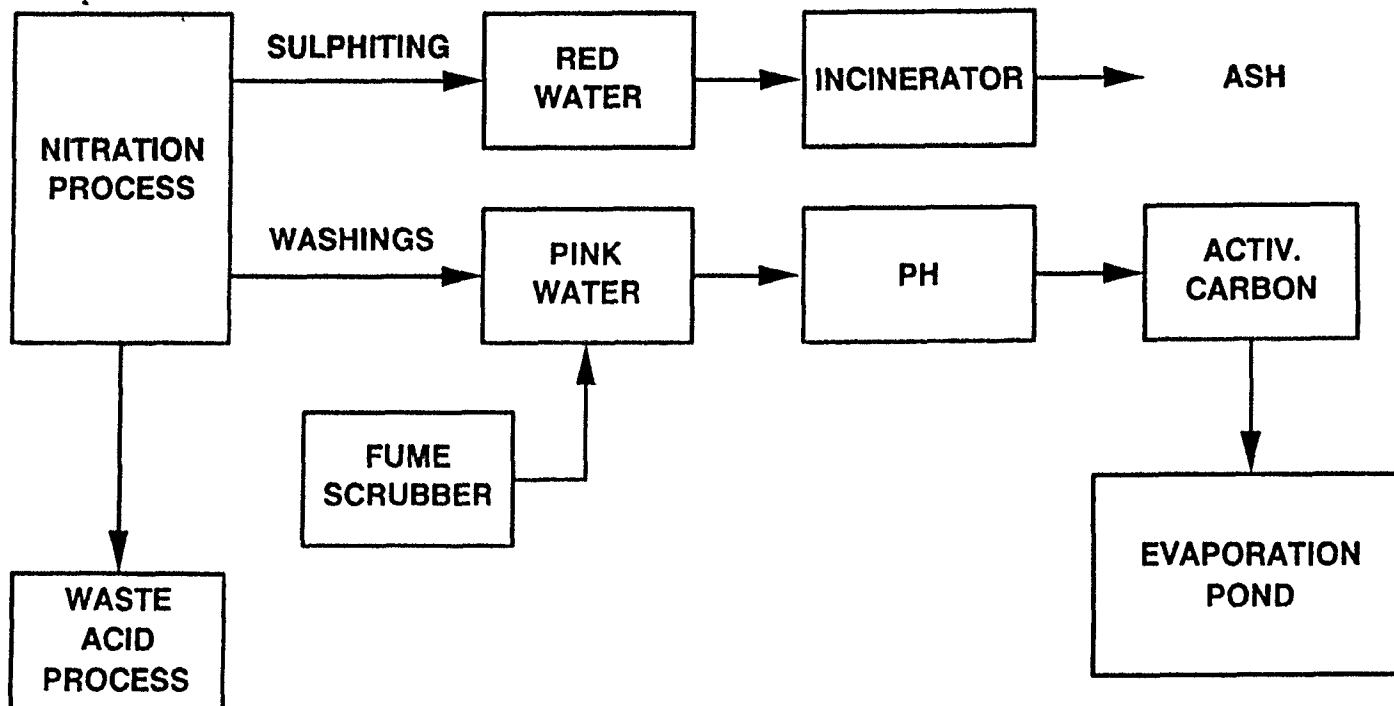
**BASIC PRINCIPLE IS ONE OF TOTAL CONTAINMENT OF PRIMARY  
LIQUID EFFLUENTS**

- . DEDICATED ON SITE EFFLUENT TREATMENT**
- . ABOVE GROUND PIPING**
- . USE OF OPEN DRAINS**
- . ACTIVATED CARBON COLUMNS**
- . SPECIALISED TREATMENTS AND PRACTICES (INCINERATION,  
CHEMICAL)**
- . NO FORMAL STORM WATER SYSTEM (SAFEGUARDING  
MEASURES TO REDUCE POTENTIAL DISCHARGE OF  
CONTAMINATED STORMWATER)**
- . BUNDING, DRAINS WITH SAVE ALL PITS**
- . WASTEWATER RECIRCULATION**
- . EVAPORATION PONDS**



## TNT WASTEWATER MANAGEMENT

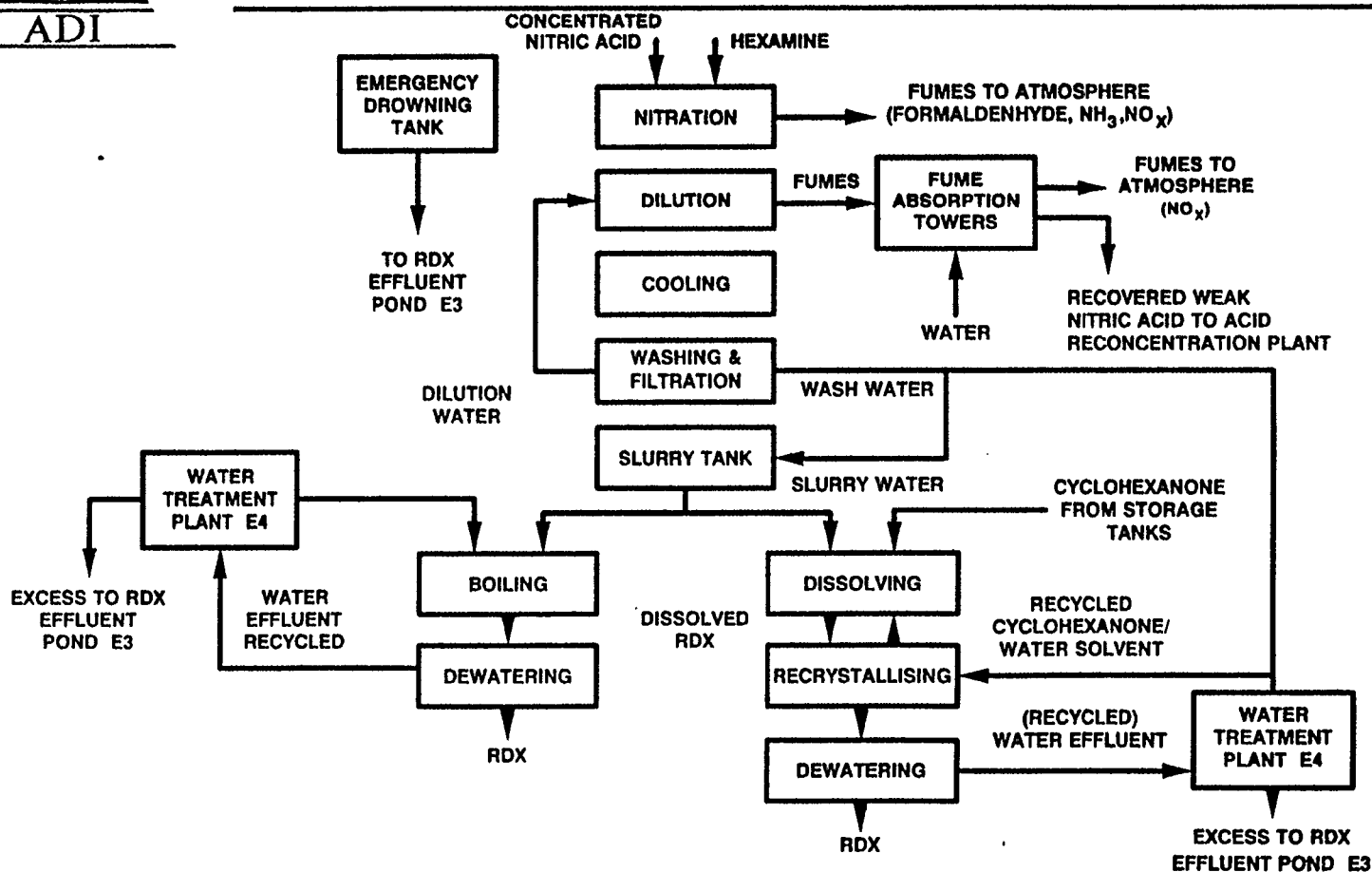
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# RDX MANUFACTURE





## **COST ESTIMATES FOR PROJECT ESTABLISHMENT**

### **INDICATIVE COSTING ESTIMATES. (RECEIVING SITE) 16/32 ha PLANTATION AREA**

<b>ITEM</b>	<b>ESTIMATED COST</b>	<b>(16ha/32ha)</b>
DETAILED DESIGN AND PROJECT PLANNING		(\$15K/\$20K)
LINED BALANCE STORAGE DAM. (23.3MI)	SUBJECT TO LOCAL QUOTATION	
3 PHASE POWER SUPPLY	AS ABOVE	
FILTRATION, CHEMICAL INJECTION PUMPING PLANT, HEADWORKS FACILITIES. (INSTALLED)		(\$30K/\$50K)



## COST ESTIMATES OF PROJECT ESTABLISHMENT

**INDICATIVE COSTING ESTIMATES. (RECEIVING SITE)  
16/32 ha PLANTATION AREA**

ITEM	ESTIMATED COST	(16ha/32ha)
MONITORING EQUIPMENT AND INSTALLATION		(\$12K/\$18K)
RIPPING, WEED CONTROL ETC	\$1,000/ha	(\$16K/\$32K)
IN-FIELD DISPERSAL SYSTEM (INSTALLED)	\$4,000/ha	(\$64K/\$128K)
PROPAGATION, PLANTING AND ESTABLISHMENT OF TREES	\$3,000/ha	(\$48K/\$96K)
SYSTEM/SITE MANAGEMENT - 0.5 MAN YEARS	\$15,000/year	(\$15K/\$25K)
ANALYSIS - MONITORING	#3,000/year	(\$3K/\$5K)





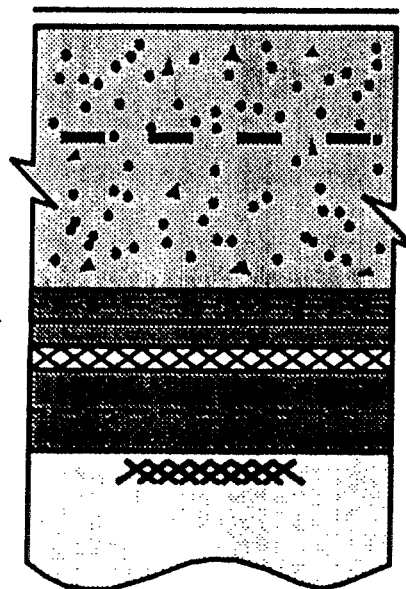
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## TYPICAL SECTION ORIGINAL DESIGN

1156

HIGH DENSITY  
POLYETHYLENE  
(H.D.P.E.) LINER  
2.5mm THICK

H.D.P.E. LINER  
1.0mm THICK



LINING SYSTEM

ACID RESISTANT  
POLYESTER

100 DEPTH REINFORCED  
CONCRETE

GEOTEXTILE MEMBRANE  
350 mg/m<sup>2</sup>

H.D.P.E. DRAINAGE NET

COMPACTED SAND  
TO 95% MMOD



## TYPICAL SECTION REVISED DESIGN

1157

PROTECTIVE  
POLYESTER  
LAYER NEAR  
ACCESS POINTS

H.D.P.E. LINER

H.D.P.E. LINER

SAND 500mm DEPTH

COMPACTED SAND

LINING SYSTEM

